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MULTIPLE UNDERGROUND EXTRACTION INFLUENCE ON THE DURATION OF LAND SURFACE DEFORMATION PROCESS

VLIV MNOHONÁSOBNÉHO PODZEMNÍHO DOBÝVÁNÍ NA TRVÁNÍ PROCESU DEFORMACE ZEMSKÉHO POVRCHU

Abstract

The empirical formula, that enables calculation of land surface deformation process duration in conditions of weak rock mass, loosened by earlier multiple extractions. This dependence may be usable in situations, where one cannot determine the moment of surface movement decay on the basis of the geodetic measurements or in forecasting of land surface movement duration caused by planned extraction.

Key words: land surface deformation process, geodetic measurement

Introduction

As the consequence of underground extraction, one can observe direct influences, indirect, as well as secondary ones (Strzałkowski, 2006). Direct influences are represented by continuous deformations in shape of subsidence troughs and their derivatives and discontinuous: superficial deformations represented by sink holes and linear deformations (cracks, fissures, terrain faults, rifts).

Indirect influences are concerned with changes in rock mass water conditions or changes in soil properties. Secondary influences arise most often as the effect of old caved workings reactivation. They may appear on the land surface in shape of sink holes in situations, where shallow old workings are undermined.

So - one can state that underground extraction essentially transforms land surface in unfavorable manner. Situation is complicated as the extraction is led under high urbanized areas, what is observed in Upper Silesia Basin in Poland.

In this paper, the analyses of geodetic measurements results have been presented, aiming at determination of land surface movement duration, caused by underground extraction. As the result of these analyses, empirical formula has been worked out, which may be usable in situations where one cannot determine the moment of surface movement decay on the basis on the geodetic measurements or in forecasting of land surface movement duration caused by planned extraction.

Carried out extraction and its influence on the land surface

In considered area intensive underground mining of limonite, zinc and lead ore as well as hard coal has been led. Old shallow workings from the XIXth century are poorly documented, in some cases there is lack of basic mining maps. Extraction of hard coal led from the beginning of the XXth century was led at greater depth – more than 150 m. Basic data concerned with carried out coal extraction has been shown in table 1.

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Table 1 Basic data concerned with carried out coal extraction.

Seam	Thickness of extracted seam [m]	Depth of extraction [m]	Extraction period [years]	Roof controlling system	Location of extraction in relation to protecting pillars determined for city districts
405	5.0	200-300	1902-08	Caving	District K.
406/4	1.2-1.4	160-370	1937-56	Stowing and caving	Districts: K. and M.
407	1.3-1.8	320-380	1940-66	Stowing and caving	Districts: K. and M.
408/2	1.4-2.0	430-450	1954-58	Caving	District K.
409	1.2-1.6	390-460	1939-60	Stowing and caving	Districts: K. and M.
411	1.4	360	1955-60	Stowing and caving	District M.
412	1.0-1.5	430-490	1950-63	Caving	Districts: K. and M.
413	2.0-2.7	520	1932-40	Caving	District M.
414/1	1.4-1.8	490-550	1958-72	Hydraulic stowing and caving	Districts: K. And M.
414/2	1.7-1.9	470-530	1965-71	Caving	Districts: K. And M.
414/3	1.4-1.7	500-570	1960-72	Caving	Districts: K. and M.
416	1.5-2.3	560-600	1944-49	Hydraulic stowing and caving	District M.
418	1.8-2.7	410-690	1939-77	Hydraulic stowing and caving.	Districts: K. and M.
419	1.8-2.1	550-710	1950-80	Hydraulic stowing and caving	Districts: K. and M.
501	2.5-4.0	600-700	1931-88	Hydraulic stowing and caving.	Districts: K. and M.
503	2.5-4.0	550-700	1940-96	Hydraulic stowing and caving	District M.
504	2.0-3.2	570-710	1939-71	Hydraulic stowing and caving.	District M.
506	1.3-1.5	720	1989-93	Caving	District M.
507	2.1-3.9	740-830	1980-2002	Caving	Districts: K. and M.

Seam	Thickness of extracted seam [m]	Depth of extraction [m]	Extraction period [years]	Roof controlling system	Location of extraction in relation to protecting pillars determined for city districts
509 upper layer	2.2-2.5	740-840	1965-2000	Caving	Districts: K. and M.
509 lower layer	2.2-2.5	740-840	1982-2003	Caving	Districts: K. and M.
510 upper layer	2.4	840	1990-2005	Caving	Districts: K. and M.
510 lower layer	2.4	845	1990-2005	Hydraulic stowing and caving	Districts: K. and M.

Table 1 cont.

Leading of extraction for more than 100 years caused land surface subsidence of significant values. The influences of this extraction are partly documented by geodetic measurements led from 1965. These measurements were led on the grid of distributed observing points stabilized on buildings and observing lines. The accessible results of measurements one can characterize as follows:

District K.

Maximum subsidence occurred in north part of district, where it reached 15.5 m. Minimum observed subsidence in this area was 3.0 m.

District M.

Maximum subsidence occurred near “S” square, where it reached 17.0 m. Numerous areas of residential buildings were subjected to subsidence from 3.0 m up to 16.0 m.

On fig.1, the distribution of subsidence over time has been presented for points located along one of the main street in this district. As it can be seen from this figure subsidence measured in the period 1988-2006 exceeded 8.0 m.

Determination of land surface subsidence duration in its terminal phase

Land surface subsidence progress in several phases. In initial phase, when extraction starts, its influence reveals gradually. When moving face of extraction working passes observing point, the main subsidence phase starts and movements are the most intensive. In this phase the rate (speed) of subsidence reaches its maximum. When extraction edge moves away or when extraction is finished, subsidence intensity decreases and lasts for certain period of time. Taking into account that extraction time is known, essential is to determine the period of time counted from finishing of extraction and land subsidence decay. In general, the moment of subsidence decay is recognized as the date of measurement when measured subsidence increase counted from previous one is not more then 10 mm. Such determination of land subsidence duration is limited in accuracy mainly by discrete character of geodetic measurements and their precision.

Important issue seems to be the influence of measured values of subsidence on the accuracy of determination of considered time. In cases when measuring points are located directly above extracted field, subsidence values are relatively high – and identification of land surface decaying moment is simple. On the other hand, when one uses outer observing points, located in certain distance from extraction edges, measured subsidence is small (max. several dozens of millimeters); obtained results may be unreliable.

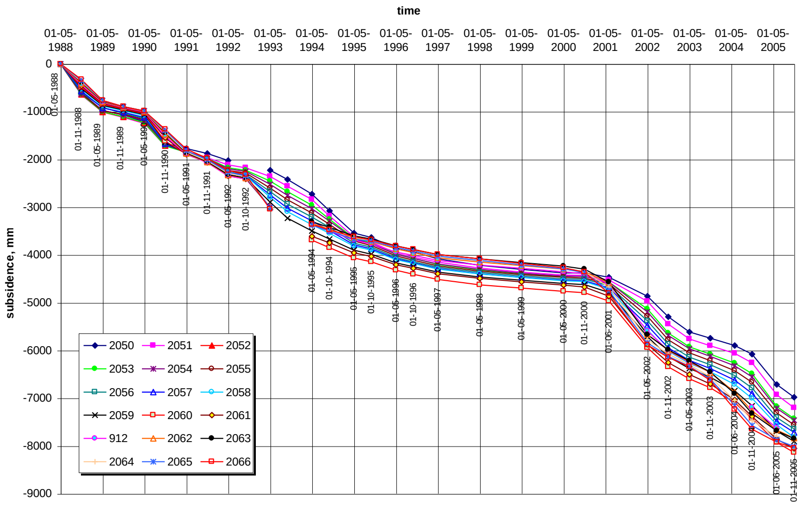

Fig.1 The distribution of subsidence over time for chosen observing points.

Taking into account above mentioned considerations, observing points were chosen located close to extraction fields for further analyses.

The duration of subsidence process depends mainly on the depth of extraction, way of roof controlling, rate of face advance speed and rock mass properties. In specific mining-geological conditions it depends primarily on the depth of extraction (Chudek, 2002; Chudek et al., 2000; Strzałkowski, 2000).

Analyses made on the basis of measurements results from considered area, brought to determining the duration time of land surface subsidence for several extraction cases, led with hydraulic stowing:

- for extraction led at the depth of 435 m: 12 months.
- for extraction led at the depth of 415 m and 485 m: 12.5 months.
- for extraction led at the depth of 495 m: 13.5 months.
- for extraction led at the depth of 570 m: 14.5 months.
- for extraction led at the depth of 565 m 17 months.
- for extraction led at the depth of 555 m and 575 m: 20 months.

By using linear regression, the formula binding the depth of extraction H with duration time of land surface subsidence T_k has been worked out:

$$T_k = 0.0452\ H - 7.573, \quad (1)$$

where:

T_k – the duration of subsidence movement in its terminal phase, months,

H – the depth of extraction, meters.

The course of Tk(H) basing on the formula (1) has been shown in fig. 2 on the background of data used for regression.

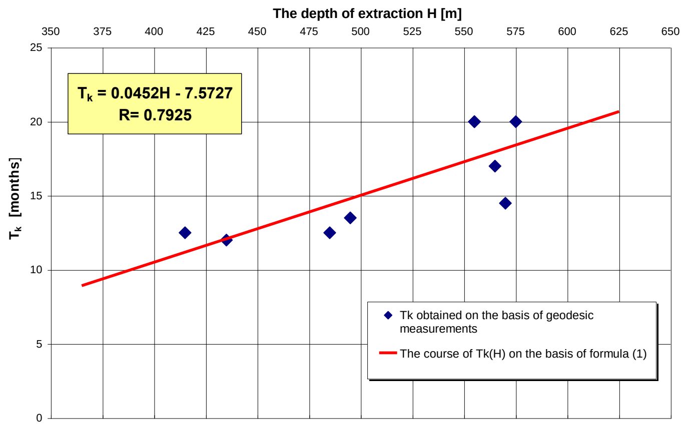

Fig.2 The course of empirical formula (1).

Summary

On the basis of analyses of geodetic measurements presented in this paper aiming at determination of land surface subsidence duration caused by underground extraction one can draw following concluding remarks:

1. High degree of rock mass loosening caused by multiple underground extractions brought about shortening of subsidence duration after extraction ending. The period of time between extraction ending (led at the depth 400 m-600 m) and subsidence decay was from 12 to 20 months.
2. Obtained empirical formula may be used for practical purposes for determining of land movement duration in cases, where one cannot determine the moment of surface subsidence decay on the basis on the geodetic measurements or in forecasting of land surface movement duration caused by planned extraction. This formula may be used only for the area, analyses of geodetic measurements were led.

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